Center for Independent Experts (CIE) Independent Peer Review Report of the Pacific Sardine Stock Assessment

Southwest Fisheries Science Center (SWFSC)

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Executive Summary

In the US, the Pacific sardine is currently a limited entry fishery managed by the Pacific Fishery Management Council using a Harvest Control Rule where the total allowable catch for a given year is based on a forward projection estimate of age 1+ biomass (mt) from the prior year assessment. The main objective of this STAR review was to evaluate two proposed alternative assessment methods for giving quota advice for 2017: (1) the Acoustic-Trawl Method (ATM) survey, which is preferred by the SWFSC stock assessment team, and (2) Model ALT which is implemented using the Stock Synthesis Model. An alternative ATM survey projection method was also considered during the review. The relatively parsimonious Model ALT reduced the parameter space compared to a standard implementation of Stock Synthesis by estimating several parameters external to the model using empirical data, and by fixing parameters. The performance of several assessment methods under the current HCR was compared based on their ability to predict a current ATM survey estimate of age 1+ biomass in the prior year´s assessment. The ATM survey method is considered to provide the most reliable estimate of the current year 1+ biomass, but the survey methods are not sufficiently documented to assess the accuracy of the estimate, and have several issues that could lead to bias in the absolute biomass estimates and associated variance. Although the ATM survey itself will be reviewed in 2018, and was not a focus of this review, all assessment methods rely heavily on survey estimate of absolute biomass of age 1+ fish. Therefore, I discuss some possible sources of bias in this review, and provide some recommendations for reducing such biases. It is well known from the literature that post-stratification based on density values observed during the survey, as was done in the ATM survey, can result in negative bias in variance estimates. The variance estimation by bootstrapping for the ATM survey also treats the transects within post-strata as simple random. This is common practice in analysis of systematically spaced transects, and is conservative since it will likely overestimate the variance for evenly spaced transects. However, in the ATM survey the handling of the adaptive component results in variable transect spacing (unequal inclusion probability) in some post-strata, which can bias the variance estimates in unknown directions when this is ignored in the analysis. The use of seasonal fixed age-length keys based on multi-year trawl survey data from 2006 can also yield biases with varying magnitude and directions in estimates of age-compositions, and will cause negative bias in variance estimates for age-compositions, and therefore estimates of age 1+ biomass. The assumption that the ATM method provides unbiased absolute biomass estimates assumes that target strength is known, and ignores vessel avoidance, incomplete survey coverage and other factors that can cause bias. Also, as revealed during this review the current forward projection method for the ATM survey method does not perform well. As currently formulated, this method performs no better than assuming no change and applying the survey estimate of age 1+ biomass in 2016 as an estimate also for age 1+ biomass in July 2017. Thus, while viable, this approach requires further development and review prior to adoption. The review panel considered Model ALT method to perform best for the current management advice that relies on a projection estimate of 1+ biomass for 2017, even though several errors in the model were discovered during the review. Major sources of uncertainty for stock assessments under the current HCR, regardless of method, is related to highly variable recruitment, growth, and uncertainty in natural mortality, *M*. Accuracy of assessments is also highly influenced by the temporal and spatial coverage of the ATM survey, the post-stratification used for estimation, insufficient sample sizes of age-length, and the use of fixed age-length keys. The assumption of multinomial distribution of numbers at age in the ATM survey method and the ALT model is likely to be unrealistic given the highly-clustered trawl sampling, causing additional errors.

Background

The National Marine Fisheries Service's (NMFS) Office of Science and Technology coordinates and manages a contract providing external expertise through the Center for Independent Experts (CIE) to conduct independent peer reviews of NMFS scientific projects. Background material and reports (Appendix A) for the review was provided by the NMFS project contact two weeks prior to the review. A Statement of Work (Annex B) is established by the NMFS Project Contact and Contracting Officer's Technical Representative, and reviewed by the CIE for compliance with their policy for providing independent expertise that can provide impartial and independent peer review without conflicts of interest.

CIE reviewers are selected by the CIE Steering Committee and CIE Coordination Team to conduct the independent peer review of NMFS science in compliance with the predetermined Terms of Reference (ToRs) of the peer review. Each CIE reviewer is contracted to deliver an independent peer review report to be approved by the CIE Steering Committee. Further information on the CIE process can be obtained from www.ciereviews.org.

This independent reviewer was requested by the Center of Independent Exerts to participate in a stock assessment review (STAR) panel to conduct independent peer review of the 2016 draft assessment by the Stock Assessment Team (STAT) for the northern subpopulation of Pacific Sardine. The STAR Panel (Appendix C), including the two CIE Reviewers, are responsible for determining if a stock assessment or technical analysis is sufficiently complete. It is their responsibility to identify assessments that cannot be reviewed or completed for any reason.

1. Description of the Reviewer's Role in the Review Activities

A peer review meeting was held at the Southwest Fisheries Science Center (SWFSC) in La Jolla, California, from February 21-24 to review a draft assessment by the Stock Assessment Team (STAT) for the northern subpopulation of Pacific Sardine. The Stock Assessment Review (STAR) panel consisted of three members of the Scientific and Statistical Committee (SSC): Dr. André Punt (University of Washington, Chair), Dr. Will Satterthwaite (SWFSC), and Dr. Evelyn Brown (Lummi Natural Resources), and two reviewers from the Center for Independent Experts (CIE): Dr. Jon Vølstad (Norway), and Dr. Gary Melvin (Canada). The STAR panel was expertly chaired by Andre Punt.

My input in the review was particularly related to statistical survey sampling methods and propagation of errors in input data through the assessment modeling that provides biomass estimates for quota advice. I have long experience and expertise in the design, analysis, and execution of fishery-independent surveys for use in stock assessments, and have experience with demersal and mid-water trawl surveys, acoustic-trawl surveys of pelagic fishes, and in the use of aerial surveys. I also have expertise in the application of fish stock assessment methods, particularly length/age-structured modeling approaches. For comments related to technical aspects of acoustic survey methods I defer to fellow CIE reviewer Gary Melvin who specializes in acoustic methods.

By way of background, I am chief scientist and leader of the Fishery Dynamics research group at Institute of Marine Research, Bergen, Norway. My education includes a bachelor with double majors in mathematics and biology, a master degree in Fishery Biology incl. management, and a Ph.D. in quantitative fisheries biology (biometrics) from University of Bergen, Norway. My PhD studies included research as a visiting scholar at Northeast Fisheries Science Center, Woods Hole, and graduate courses in mathematical statistics at University of Bergen and at the Department of Biomathematics (now department of Statistics),

Oxford University (UK), as a British Council Scholar. My dissertation was on survey design and analysis of abundance surveys. I have more than 25 years of international research experience in statistical survey methods, quantitative fisheries biology, and statistical ecology from academia, national institutes, and private industry. My research primarily focuses on the development and optimization of statistical survey techniques for assessment of fisheries resources and the environment, and the quantification of uncertainty in stock assessments.

My preparations in advance of the peer review meeting included a review of background material and reports (Appendix A) provided by the SWFSC Project Contact Dr. Dale Sweetnam (SWFSC) via email on February 7 via link to ftp-site. This was a very effective way of distributing the extensive material. All the presentations (see below) were added to the ftp site during the review meeting.

A series of very informative power point presentations were given during the review meeting by the SWFSC Stock Assessment Team. My fellow peer reviewers and I asked questions during the presentations and participated in the panel discussions on validity, results, recommendations, and conclusions. Will Satterthwaite (SSC, SWFSC) acted as rapporteur.

Drs. Paul Crone, Kevin Hill, and Juan Zwolinski presented the assessment methodology. Two alternative assessment approaches were presented:

1. Direct use of the summer 2016 Acoustic Trawl Method (ATM) survey estimate and associated age-composition projected to 1 July 2017, which is the method preferred by SWFSC, and

2. Model ALT which is a model-based assessment that provides an estimate of age 1+ biomass on 1 July 2017 based on a modified more parsimonious Stock Synthesis model where many parameters are estimated externally from empirical data.

Juan Zwolinski described the survey-based method for estimating age 1+ biomass on 1 July 2017 that involved:

- estimating numbers-at-age on 1 July 2016 from the summer 2016 ATM survey from numbers-at-length using an age-length key that pooled data over multiple summer surveys, and
- projecting these numbers forward accounting for natural mortality and growth, and adding the estimated recruitment for 2016. The recruitment for 2016 was based on the stock-recruitment relationship estimated by model ALT, and the spawning stock biomass for 2016 was estimated by back-projecting the summer 2016 numbers-at-age to 1 January 2016.

Kevin Hill and Paul Crone described the data on which the model-based assessment was based, as well the results from a draft assessment utilizing the Stock Synthesis Assessment Tool, Version 3.24aa. Model ALT differed from the model on which the 2016 update assessment was based by:

- starting the assessment in 2005 rather than 1993,
- excluding the Daily Egg Production Method (DEPM) and Total Egg Production (TEP) indices,
- estimating rather than pre-specifying stock-recruitment steepness,
- pre-specifying weight-at-age rather than estimating it within the assessment,
- assuming selectivity for the ATM survey to be zero for age 0 and uniform for age 1 and older,
- estimating survey catchability (Q), assuming selectivity to be age- rather than length-based,
- modelling ages 0-10+yr rather than ages 0-15+yr, assuming natural mortality (M) is 0.6yr-1 rather than 0.4yr-1 for all age classes and fitting the catch and ATM survey age-composition data (rather than the associated length-composition data).

Unlike the 2016 and earlier assessments, model ALT included additional live bait landings, which generally reflected a minor contribution to the total landings in California in the past. However, model ALT did not include biological composition data from the live bait catches, given this fishery sector had not been regularly sampled in the past, with samples being available for only the most recent year of the time series modelled in the assessment.

The review and request by the STAR panel for additional analysis during the meeting were motivated primarily by the need to better understand the rationale for model ALT, and to identify the best approach for providing a projection of age 1+ biomass on 1 July 2017 that is currently required by management. The Panel had several comments and concerns regarding the ATM survey methodology and ways in which estimates of close-to-absolute abundance can be obtained. However, this was not a review of the ATM survey, since a second Council-sponsored ATM methodology review is planned for early 2018. Therefore, comments in the Panel Report regarding the ATM survey and how estimates of abundance from that survey are constructed are reflected primarily in the Research Recommendations section of the report. However, since both assessment methods considered in the review strongly depends on the ATM survey, I have made several comments in the next section, and in section (3).

2. Findings by ToR

The bibliography list (Appendix A) and the Statement of Work (Appendix B) describe the documents reviewed and review activities, respectively, as part of an independent peer review completed for the Center for Independent Experts (CIE).

2.1. Acoustic Trawl Method (ATM) Survey Assessment

In the assessment approach based on the ATM survey two methods are used to project the current (2016) estimate of age 1+ biomass to an estimate of age1 biomass for 2017. The preferred approach in the Draft Stock Assessment Document projecting the biomass from the 2016 ATM survey to 1 July 2017 accounting for mortality, growth and recruitment from July 2016 to July 2017. However, the approach used to convert from length composition to age composition is incorrect, and the method used to derive the CV of age 2+ biomass does not allow for uncertainty in population age composition, projected weight-at-age and maturity-at-age. In addition, the method relies heavily on model ALT because approximately half of the age 1+ biomass on 1 July 2017 consists of age-1 animals, i.e. the estimate of this biomass is based to a substantial extent on the stock-recruitment function from model ALT. Finally, the value for M of 0.6yr-1 has no clear justification. The version of the projection model provided initially to the Panel did not account for catches so it could not be applied were the targeted sardine fishery to be re-opened, and does not account for the limited catches during 2016. An alternative assessment based on the ATM survey proposed during the review meeting assume that the 1 July 2017 biomass equals the estimate of biomass from the summer 2016 ATM survey. This “projection” ignores mortality (from natural causes and from fishing), growth and recruitment from July 2016 to July 2017. However, this method is simple to implement because it does not rely on a model, nor does it rely on highly uncertain recruitment estimates and estimates of age composition for which sample sizes are low.

The Panel had several comments and concerns regarding the ATM survey methodology and ways in which estimates of close-to-absolute abundance can be obtained. In a prior CIE review in 2011, it was concluded that there are no major problems with acoustic technique and methodology and it was the best that could be used at that time. Although this is not a review of the ATM survey, since a second Council-sponsored

ATM methodology review is planned for early 2018, I have several comments in section (3) since the ATM survey results are critical input to all assessment models being evaluated.

2.2. Model ALT Assessment

The final model (model ALT) incorporates the following specifications:

- catches for the MexCal fleet computed using the environmentally-based method;
- two seasons (semesters, Jul-Dec=S1 and Jan-Jun=S2) for each assessment year from 2005 to 2016;
- sexes were combined; ages 0-10+.
- two fisheries (MexCal and PacNW fleets), with an annual selectivity pattern for the PacNW fleet and seasonal selectivity patterns (S1 and S2) for the MexCal fleet;
  - MexCal fleet: age-based selectivity (one parameter per age)
  - PacNW fleet: asymptotic age-based selectivity;
  - age-compositions with effective sample sizes calculated by dividing the number of fish sampled by 25 (externally) and lambda weighting=1 (internally);
- Beverton-Holt stock-recruitment relationship with "steepness" estimated;
- *M* was fixed (0.6 yr^{-1});
- recruitment deviations estimated from 2005-2015;
- virgin recruitment estimated, and σ_R fixed at 0.75;
- initial *F*s estimated for the MexCal S1 fleet and assumed to be 0 for the other fleets;
- ATM survey biomass 2006-2013, partitioned into two (spring and summer) surveys, with Q estimated;
  - age-compositions with effective sample sizes set to 1 per cluster (externally);
  - selectivity is assumed to be uniform (fully-selected) above age 1 and zero for age 0.

The estimate of age 1+ biomass on 1 July 2017 from model ALT is 86,586t (CV 0.363). Model ALT indicates that age 1+ biomass has rebuilt close to that in 2014, owing to a substantial increase in biomass based on the indices from the survey.

Model ALT has several of the problems associated with the 'survey projection' model, i.e. the age-composition data are based on a year-invariant age-length key, and the basis for M=0.6yr-1 lacks strong empirical justification (and indeed likelihood profiles indicate some support for lower M than the value adopted for model ALT). In addition, the model presented to the Panel predicted age-0 catch in the ATM survey even though it is assumed that age-0 animals are not selected during the ATM survey. It appears that Stock Synthesis with the ALT parametrization predicts some catch of nominal "age 0" even when the selectivity is set to zero for age-0 fish. The STAR review panel requested several additional model runs to gain insights, because aging error could result in some age-1 fish in catches being misclassified as age 0. Furthermore, model runs revealed that the model was unable to converge if aging error was set to zero or made very small, but reductions in the specified aging error led to the expected reduction in the predicted age-0 catch. It was noted that surveys likely include a mix of age-1 fish misclassified as age-0, as well as fish that are truly age 0. Dr. Methot has also noted that Stock Synthesis had not been as thoroughly debugged for semester-based models as for strictly annual models

2.3. Evaluating the Performance of Assessment Approaches

The performance of several assessment methods under the current HCR was compared based on their ability to predict a current ATM survey estimate of age 1+ biomass in the prior year´s assessment. The

STAR review considered four methods:

a) ATM survey method using the 1+ biomass estimate from the prior year as is,
    i. This assumption ignores mortality (from natural causes and from fishing), growth and recruitment from July 2016 to July 2017.
b) ATM survey method projecting the biomass from the prior summer ATM survey estimate using the 'survey projection' model (or an alternative approach),
c) Model ALT assessment and projection, and for comparison,
d) the assessment model and projection on which the 2014-16 estimates of biomass were based.

Results are provided in Fig. 4 from the STAR Panel.

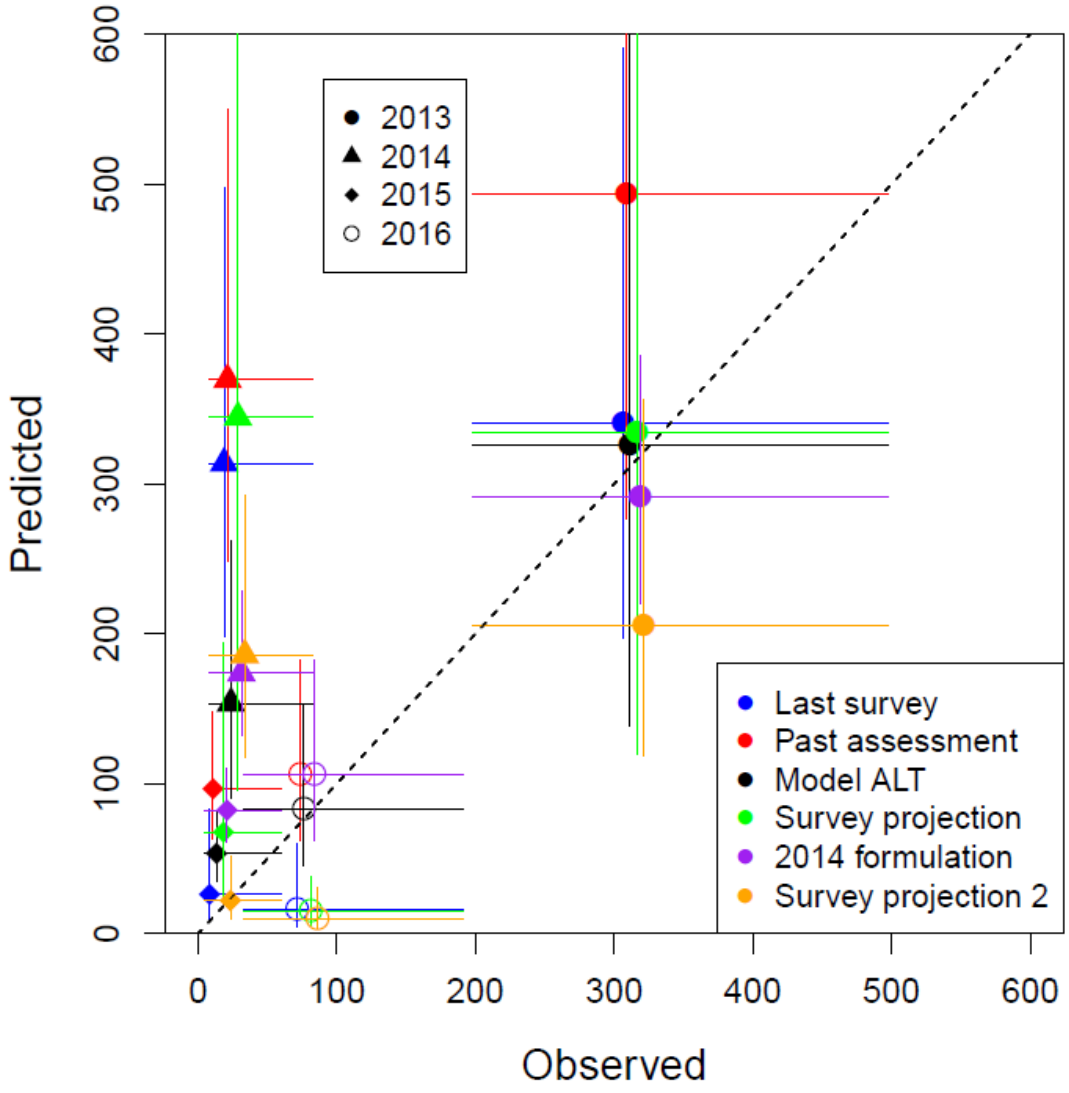

Fig. 4. (From Final Report of Sardine STAR Panel). Observed (x-axis values, ATM survey biomass estimates) and model-predicted (y-axis values) biomass on 1 July of each of 2013, 2014, 2015 and 2016. The observed values are the summer ATM survey estimates. The lines indicate 90% confidence intervals under the assumption of log-normal error. The x-axis values are jittered for ease of presentation.

The Panel had concerns with these methods. The ATM survey is considered to provide the most reliable estimate of the current year 1+ biomass, but the survey design and analysis methods are not sufficiently

documented to assess the accuracy of the estimate, and have several issues that could lead to bias in the absolute biomass estimates and associated variance. Projecting the biomass from the 2016 ATM survey to 1 July 2017 (Method b) accounts for mortality, growth and recruitment from July 2016 to July 2017. However, the approach used to convert from length composition to age composition using fixed seasonal age-length keys based on data since 2006 is incorrect, and the method used to derive the CV of age 2+ biomass does not allow for uncertainty in population age composition, projected weight-at-age and maturity-at-age. In addition, the estimate of this biomass is based to a substantial extent on the stock-recruitment function from model ALT. Finally, the value for M of 0.6yr-1 has no clear justification.

Model ALT (Method c) has several of the problems associated with the 'survey projection' model, i.e. the age-composition data are based on a fixed age-length key, and the basis for M=0.6yr-1 lacks strong empirical justification. In addition, the model presented to the Panel predicted age-0 catch in the ATM survey even though it is assumed that age-0 animals are not selected during the ATM survey. Also, Model ALT estimates Q to be 1.1, which is unlikely given some sardine are not available to the survey owing to being inshore of the survey area.

The model (d) on which the 2014-16 assessments were based was approved for management by the 2014 STAR Panel. However, that assessment had some undesirable features, including extreme sensitivity to the occurrence of small (<~15cm fish) in the ATM surveys, poor fits to the length-composition and survey data, and sensitivity to the initial values for the parameters (i.e. local minima). These sensitivities and the resultant high uncertainty about population scale were noted in previous reviews.

The Panel explored alternatives to the current selectivity formulation to better understand why model ALT was predicting age-0 catch when selectivity for age-0 fish was set to zero. It was noted that the results are generally robust to the assumption that selectivity is a logistic function of length, allowing for time-varying age-0 selectivity, and estimating a separate selectivity pattern for ATM survey age-composition data.

The Panel noted that the 'survey projection' model and model ALT both rely on the samples from the ATM surveys to compute weight-at-age and survey age-composition data. These estimates are highly uncertain since the samples sizes for age from each survey are very small (16 – 1,051 fish; and VERY few trawl clusters which are the primary sampling units for the age-comps).

3. Conclusions and Recommendations

The SWFSC assessment scientists (STAT) did an outstanding job presenting the assessment results, and were very helpful throughout the review meeting by providing additional analysis upon request and answering questions related to the panel's interpretation of the available data and results. The panel members had broad and complimentary expertise that covered all the review subjects. The effectiveness of the review process was substantially enhanced by the expert leadership of the chair, Andre Punt, and the panel greatly benefited from the input from the Pacific Fishery Management Council, and representatives from the fishing industry. One criticism I have is that the stock assessment report and material provided that formed the basis for the review provided insufficient details to fully assess the quality of the input-data and model specification. I recognize that the stock assessment scientists responsible for the report may have had insufficient time to fully document the methods.

The STAR panel cautiously recommended proceeding with Model ALT, as the "least-worst" way to produce the age 1+ biomass estimate and CV required for management in 2017. Given the current

HCR, the Panel and STAT agreed that model ALT was the best approach at present for conducting an assessment for the northern subpopulation of Pacific sardine, notwithstanding the concerns listed above. The alternative assessment approaches provided more uncertain predictions of age 1+ biomass July 1, 2017:

- The approach on which 2014-16 management was based exhibited undesirable assessment diagnostics, and produced extremely high estimates of recruitment when large numbers of small fish were observed in the ATM survey length-frequencies. The approach also performed poorly in retrospective analysis (Fig. 4). The Panel and STAT agreed that this approach should not be used for 2017 management.
- The survey projection method (and the modified version, "Survey projection 2") seems a viable and defensible way to estimate age 1+ biomass using the ATM survey results, especially if the method could be modified to not use the results from model ALT. However, as currently formulated, this method performs no better than assuming the age 1+ biomass in July 2017 equals the survey estimate of biomass for summer 2016 (Fig. 4). Thus, while viable, this approach requires further development and review prior to adoption.
- Estimating the biomass on 1 July of year Y+1 based on the ATM survey estimate for year Y is simple, but the Panel was concerned that this method ignored catches during year Y and may lead to additional risk. Thus, the basic approach is viable, but needs additional testing prior to adoption.

I agree fully with these recommendations in the STAR review report on how management could be based on the ATM survey results:

- Change the start-date of the fishery so that the time between conducting the survey and implementation of harvest regulations is minimized.
- Use Management Strategy Evaluation to evaluate the risk to the stock of basing management actions on an estimate of biomass that could be a year old at the start of the fishing season (if the fishery start date is unchanged). Review of an updated MSE would likely not require a Methodology Panel, but could instead be conducted by the SSC.

As the review Panel noted, there may be benefits in using both the spring and summer ATM surveys as the basis for the assessment. Relying an ATM survey based assessment approach that relies on an estimate for the current year may be compromised by proposed reductions in ship time and/or problems conducting the survey. Also, as pointed out by the STAT there is value in continuing to collect biological data and to update model ALT even if management moves to an ATM survey-only approach.

In the following section, I have some more comments on the STM survey, and recommendations for future documentation and analysis.

Acoustic Trawl Method Survey

The systematic design for acoustic-trawl survey is robust for covering Pacific sardine with varying patchiness and areas of occupancy, provided that the spatial coverage E-W and N-S is adequate. The acoustic survey transect design is systematic with a close to regular spacing of transects allocated in advance, and adaptive component with reduced transect spacing in some areas of expected high abundance. Abundance and biomass is estimated by treating transects as simple random samples within post-strata, and the variance is estimated by bootstrap with equal selection probability of

transects. However, based on provided material, documents, and discussions during this review it is apparent that the ATM survey is not based on probabilistic sampling design where every transect (primary sampling unit, PSU) has a known probability of being selected. The adaptive sampling component where additional acoustic transects are added in areas with observed high density of Pacific sardines is not well documented, and appears to be ad-hoc. The post-stratification of transects used in the estimating abundance and biomass by age class takes are based on sampling intensity (spacing of transects) and measured density. The grouping of transects with low density into separate strata is inappropriate and likely to cause bias in the variance estimates. Also, even though SWFSC staff argued that transects within all post-strata have equal spacing (and selection probability), this is not documented and is contradicted by figures presented during the review showing post-strata and acoustic transects.

Before the upcoming 2018 review of the ATM survey, it is strongly recommended that SWFSC specify the survey design and estimation methods in sufficient details. A document should be provided to the ATM review (and future assessment STAR Panels) that:

- delineates the annual survey area (sampling frame);
- specifies the spatial stratification (if any) and transect spacing within strata planned (true stratification);
- specifies the rule for stopping a transect (offshore boundary);
- specifies the rules for conducting trawls to determine species composition;
- specifies the rule for adaptive sampling (including the start and stopping rule); and
- specifies rules for post-stratification, and how density observations are considered in post-stratification.
- alternative post-stratification without considering density should be considered.

It is particularly important that the sampling frame covers the area of occupancy, that allocation of transects be based on probabilistic methods and that biases be minimized. The systematic allocation of transects with random start, and known selection probabilities, provides unbiased estimates of means and totals provided that the estimators apply weights that consider the probabilities of selection. However, systematic sampling precludes unbiased analytical variance estimates, and if the systematic survey is treated as simple random the estimated variance is likely to be biased upwards (Cochran, 1977). The systematic transect survey can also be considered a stratified sampling design with 1 PSU (transect) in each spatial stratum. A common approach to approximate the variances in estimates of means and totals in systematic designs is to group neighboring strata to yield a pseudo design with more than one PSU per stratum that is treated as it were the actual design (Wolter, 1985; Dunn and Harrison, 1993, Korn and Graubard, 1999). The variance and the relative standard error (RSE) (Jessen, 1978) is then estimated under the assumption of simple random sampling within the collapsed strata (Fuller, 2009). See Nøttestad et al. (2017) for an application for trawl sampling of mackerel.

The sardine habitat model based on remotely sensed SST, chlorophyll, and sea-surface gradient (Zwolinski et al. 2011) is currently used to (1) develop the sampling frame, and (2) assign catches to subpopulation but not to allocate sampling effort within the survey area, which is based on an ad-hoc adaptive sampling with denser spacing of transects in areas with high density of sardine. One reason for this adaptive component, with use of post-stratification in the analysis, instead of stratifying in advance (true stratification) on habitat is that the habitat is very dynamic even within the time period of the surveys. It is strongly recommended that the best available models be used for sample allocation, and that any real-time adaptive component be conducted using methods that minimizes bias (see for example, Harbitz et al. 2009; Thomposon and Seber 2009).

Assuming we have defined the sampling frame using a model, allocation based on the model will only affect precision, and even a relatively crude model that can identify areas with higher than average density will likely give better precision than equal spacing throughout the survey area. The habitat model predicts probabilities of capture for broad categories of habitat (e.g., "optimal", "good", "unsuitable" habitat). This is fine for defining the sampling frame but for sample allocation/stratification, the distribution of model predictions should be used to create strata that are most similar within. Alternative model approaches should also be considered for stratification. Ed Weber (SWFSC) is currently working with a sardine habitat model based on a ROMS model (Wang and Chao 2004) coupled with a biological model known as CoSiNE (Carbon, Silicate, Nitrogen Ecosystem model Chai et al., 2002; Liu and Chai, 2009). He demonstrated the model to me after the review meeting. Based on simulations of historic surveys he is testing if stratification based on modeled habitat could improve the precision of acoustic surveys. Using modeled data for stratification, and to allocate more transects (with known probability) to strata that are expected to have high density and variance, instead of satellite data, appears to have a several advantages. It is mechanistic, at least to the level of secondary production. It does not suffer from data gaps due to cloud cover. It could potentially be projected into the future for short periods.

Clearly, the changes in spatial distributions over time, both horizontally and vertically, may introduce biases in acoustic indices of abundance of changing magnitudes and directions. Such biases can be caused by vessel avoidance, acoustic shadowing and depth dependent acoustic target strength (Skaret et al., 2005; Løland et al., 2007; Hjellvik et al., 2008). Random sampling errors in acoustic survey indices of abundance due to spatial sampling has been shown to be the main source of uncertainty in acoustic measurements of abundance (Rose et al. 2000). Løland et al. (2007) investigated several additional sources of error in acoustic survey estimates of the Norwegian Spring Spawning herring stock in the wintering area. They did, however, conclude that acoustic sampling error (variation among transects) was the largest contributor to the total uncertainty of the estimate. The ATM surveys at present do not capture fish in the upper water column, and appears to miss a large biomass of young fish (sizes 3 inches and up) that fishermen have observed in nearshore waters since late 2014; this biomass is largely inside ATM survey tracks. The SWFSC plans to examine ship avoidance using aerial drone sampling. There is an ongoing significant effort by Institute of Marine Research in Norway to understand the same issue using sonar, and the SWFSC acoustics team should communicate and coordinate with those researchers. The possible bias due to not detecting fish that are near the surface by acoustics could be investigated using sonar. This is currently being done in acoustic-trawl surveys for herring by Institute of Marine Research, Norway, and is addressed in a large effort to reduce uncertainty in stock assessments (REDUS project: www.redus.no).

Trawl sampling and the estimation of age-compositions

The current practice of treating data on numbers-at-age from the trawl survey as multinomial is problematic because the trawl samples are clustered, and age-samples are subsamples from trawl hauls. This is likely to result in cluster effects, resulting in correlation among age-groups (see ICES 2016a,b, 2017, and Aanes and Vølstad 2016). It is recommended that the age-data be evaluated. Ideally, it would be possible to run bootstrap resampling on the PSUs to create replicated Model ALT runs that reflect the complexity in input data. See the Norwegian Spring-spawning Herring case study under the REDUS project in ICES WKCOSTBEN (ICES 2017) for an example where the more complex error structure in input data is accounted for. The statistical assessment model XSAM (developed by Sondre Aanes, Norwegian Computing Centre) has been chosen for the assessment of Norwegian Spring Spawning Herring by ICES Benchmark assessments (2016a,b) because it can take into account the complex error structure in input-

data in age-based assessment.

It is further recommended that the level of biological sub-sampling and data collections at each trawl station (or clusters of trawl stations) be evaluated through simulations to see how subsample size at the trawl stations affects the precision in estimates of numbers at age through age-length keys for the combined acoustic-trawl survey. The effective sample size for estimating age is likely to be driven by the number of transects and trawl stations sampled, and may be little affected by the sub-sample sizes of fish that are aged at each trawl station. Stewart and Hamel (2014) and Aanes and Vølstad (2015) have shown that it is sufficient to collect ~10-20 ages from each station to estimate the age distribution and that higher numbers of age-samples will only marginally improve the precision in estimates of age-composition, since the variance is driven by the number of PSUs sampled (number of trawl stations). Results in Nøttestad et al. (2017) show that for Atlantic mackerel the collections of extra length samples within trawl stations, and trawl stations with length-only samples can increased the precision in the estimates of abundance indices at age for age groups that occur in low proportions.

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Appendix 2: Copy of Statement of Work

Statement of Work
National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service (NMFS)
Center for Independent Experts (CIE) Program External Independent Peer Review

STAR Panel Review of the 2017-2018 Pacific Sardine Stock Assessment

February 21-24, 2017

Background

The National Marine Fisheries Service (NMFS) is mandated by the Magnuson-Stevens Fishery Conservation and Management Act, Endangered Species Act, and Marine Mammal Protection Act to conserve, protect, and manage our nation's marine living resources based upon the best scientific information available (BSIA). NMFS science products, including scientific advice, are often controversial and may require timely scientific peer reviews that are strictly independent of all outside influences. A formal external process for independent expert reviews of the agency's scientific products and programs ensures their credibility. Therefore, external scientific peer reviews have been and continue to be essential to strengthening scientific quality assurance for fishery conservation and management actions.

Scientific peer review is defined as the organized review process where one or more qualified experts review scientific information to ensure quality and credibility. These expert(s) must conduct their peer review impartially, objectively, and without conflicts of interest. Each reviewer must also be independent from the development of the science, without influence from any position that the agency or constituent groups may have. Furthermore, the Office of Management and Budget (OMB), authorized by the Information Quality Act, requires all federal agencies to conduct peer reviews of highly influential and controversial science before dissemination, and that peer reviewers must be deemed qualified based on the OMB Peer Review Bulletin standards. (http://www.cio.noaa.gov/services_programs/pdfs/OMB_Peer_Review_Bulletin_m05-03.pdf). Further information on the CIE program may be obtained from www.ciereviews.org.

Scope

The CIE reviewers will serve on a Stock Assessment Review (STAR) Panel and will be expected to participate in the review of Pacific sardine stock assessment. The Pacific sardine stock is assessed regularly (currently, every 1-2 years) by SWFSC scientists, and the Pacific Fishery Management Council (PFMC) uses the resulting biomass estimate to establish an annual harvest guideline (quota). The stock assessment data and model are formally reviewed by a Stock Assessment Review (STAR) Panel once every three years, with a coastal pelagic species subcommittee of the SSC reviewing updates in interim years. Independent peer review is required by the PFMC review process. The STAR Panel will review draft stock assessment documents and any other pertinent information for Pacific

sardine, work with the stock assessment teams to make necessary revisions, and produce a STAR Panel report for use by the PFMC and other interested persons for developing management recommendations for the fishery. The PFMC's Terms of Reference (ToRs) for the STAR Panel review are attached in Appendix 1. The tentative agenda of the Panel review meeting is attached in Appendix 2. Finally, a Panel summary report template is attached as Appendix 3.

Requirements

Two CIE reviewers shall participate during a panel review meeting in La Jolla, California during 21-24 February, and shall conduct impartial and independent peer review accordance with the SoW and ToRs herein. The CIE reviewers shall have the expertise as listed in the following descending order of importance:

- The CIE reviewer shall have expertise in the design and execution of fishery-independent surveys for use in stock assessments, preferably with coastal pelagic fishes

- The CIE reviewer shall have expertise in the application of fish stock assessment methods, particularly, length/age-structured modeling approaches, e.g., 'forward-simulation' models (such as Stock Synthesis, SS) and it is desirable to have familiarity in 'backward-simulation' models (such as Virtual Population Analysis, VPA).
- The CIE reviewer shall have expertise in the life history strategies and population dynamics of coastal pelagic fishes.
- It is desirable for the CIE reviewer to be familiar with the design and application of fisheries underwater acoustic technology to estimate fish abundance for stock assessment.
- It is desirable for the CIE reviewer to be familiar with the design and application of aerial surveys to estimate fish abundance for stock assessment.

The CIE reviewer's duties shall not exceed a maximum of 14 days to complete all work tasks of the peer review process.

Tasks for reviewers

- Review the following background materials and reports prior to the review meeting: *Two weeks before the peer review, the NMFS Project Contact will send by electronic mail or make available at an FTP site to the CIE reviewers all necessary background information and reports for the peer review. In the case where the documents need to be mailed, the NMFS Project Contact will consult with the CIE on where to send documents. The CIE reviewers shall read all documents in preparation for the peer review, for example:*

    - *Recent stock assessment documents since 2013;*
    - *STAR Panel- and SSC-related documents pertaining to reviews of past assessments;*
    - *CIE-related summary reports pertaining to past assessments; and*
    - *Miscellaneous documents, such as ToR, logistical considerations.*

Pre-review documents will be provided up to two weeks before the peer review. Any delays in submission of pre-review documents for the CIE peer review will result in delays with the CIE peer review process, including a SoW modification to the schedule of milestones and deliverables. Furthermore, the CIE reviewers are responsible only for the pre-review documents that are delivered to the reviewer in accordance to the SoW scheduled deadlines specified herein.

- Attend and participate in the panel review meeting
    - The meeting will consist of presentations by NOAA and other scientists, stock assessment authors and others to facilitate the review, to provide any additional information required by the reviewers, and to answer any questions from reviewers
- After the review meeting, reviewers shall conduct an independent peer review in accordance with the requirements specified in this SOW, OMB guidelines, and TORs, in adherence with the required formatting and content guidelines; reviewers are not required to reach a consensus
- Each reviewer may assist the Chair of the meeting with contributions to the summary report, if required by the TORs
- Deliver their reports to the Government according to the specified milestone dates

Foreign National Security Clearance

When reviewers participate during a panel review meeting at a government facility, the NMFS Project Contact is responsible for obtaining the Foreign National Security Clearance approval for reviewers

who are non-US citizens. For this reason, the reviewers shall provide requested information (e.g., first and last name, contact information, gender, birth date, passport number, country of passport, travel dates, country of citizenship, country of current residence, and home country) to the NMFS Project Contact for the purpose of their security clearance, and this information shall be submitted at least 30 days before the peer review in accordance with the NOAA Deemed Export Technology Control Program NAO 207-12 regulations available at the Deemed Exports NAO website: http://deemedexports.noaa.gov/ and http://deemedexports.noaa.gov/compliance_access_control_procedures/noaa-foreign-national-registration-system.html. The contractor is required to use all appropriate methods to safeguard Personally Identifiable Information (PII).

Place of Performance

The place of performance shall be at the contractor's facilities, and at the Southwest Fisheries Science Center in La Jolla, California.

Period of Performance

The period of performance shall be from the time of award through April 30, 2017. Each reviewer's duties shall not exceed 14 days to complete all required tasks.

Schedule of Milestones and Deliverables:

The contractor shall complete the tasks and deliverables in accordance with the following schedule.

No later than January 24, 2017	CIE sends reviewers contact information to the COTR, who then sends this to the NMFS Project Contact
No later than February 7, 2017	NMFS Project Contact sends the CIE Reviewers the pre-review documents
February 21-24, 2017	The reviewers participate and conduct an independent peer review during the panel review meeting
March 10, 2017	CIE reviewers submit draft CIE independent peer review reports to the CIE Lead Coordinator and CIE Regional Coordinator
March 31, 2017	CIE submits CIE independent peer review reports to the COTR
April 7, 2017	The COTR distributes the final CIE reports to the NMFS Project Contact and regional Center Director

Applicable Performance Standards

The acceptance of the contract deliverables shall be based on three performance standards: (1) The reports shall be completed in accordance with the required formatting and content (2) The reports shall address each TOR as specified (3) The reports shall be delivered as specified in the schedule of milestones and deliverables.

Travel

All travel expenses shall be reimbursable in accordance with Federal Travel Regulations

(http://www.gsa.gov/portal/content/104790). International travel is authorized for this contract. Travel is not to exceed $10,000.

Restricted or Limited Use of Data

The contractors may be required to sign and adhere to a non-disclosure agreement.

Peer Review Report Requirements

1. The report must be prefaced with an Executive Summary providing a concise summary of the findings and recommendations, and specify whether or not the science reviewed is the best scientific information available.

2. The report must contain a background section, description of the individual reviewers' roles in the review activities, summary of findings for each TOR in which the weaknesses and strengths are described, and conclusions and recommendations in accordance with the TORs.

   a. Reviewers must describe in their own words the review activities completed during the panel review meeting, including a brief summary of findings, of the science, conclusions, and recommendations.

   b. Reviewers should discuss their independent views on each TOR even if these were consistent with those of other panelists, but especially where there were divergent views.

   c. Reviewers should elaborate on any points raised in the summary report that they believe might require further clarification.

   d. Reviewers shall provide a critique of the NMFS review process, including suggestions for improvements of both process and products.

   e. The report shall be a stand-alone document for others to understand the weaknesses and strengths of the science reviewed, regardless of whether or not they read the summary report. The report shall represent the peer review of each TOR, and shall not simply repeat the contents of the summary report.

3. The report shall include the following appendices:

   Appendix 1: Bibliography of materials provided for review
   Appendix 2: A copy of this Statement of Work
   Appendix 3: Panel membership or other pertinent information from the panel review meeting.

Appendix 1: Terms of Reference for the Peer Review of the Pacific sardine stock assessment

The CIE reviewers are one of the four equal members of the STAR panel. The principal responsibilities of the STAR Panel are to review stock assessment data inputs, analytical models, and to provide complete STAR Panel reports.

Along with the entire STAR Panel, the CIE Reviewer's duties include:

1. Reviewing draft stock assessment and other pertinent information (e.g.; previous assessments and STAR Panel reports);
2. Working with STAT Teams to ensure assessments are reviewed as needed;
3. Documenting meeting discussions;
4. Reviewing summaries of stock status (prepared by STAT Teams) for inclusion in the Stock Assessment and Fishery Evaluation (SAFE) document;
5. Recommending alternative methods and/or modifications of proposed methods, as appropriate during the STAR Panel meeting, and;
6. The STAR Panel's terms of reference concern technical aspects of stock assessment work. The STAR Panel should strive for a risk neutral approach in its reports and deliberations.

The STAR Panel, including the CIE Reviewers, are responsible for determining if a stock assessment or technical analysis is sufficiently complete. It is their responsibility to identify assessments that cannot be reviewed or completed for any reason. The decision that an assessment is complete should be made by Panel consensus. If agreement cannot be reached, then the nature of the disagreement must be described in the Panels' and CIE Reviewer's reports.

The review solely concerns technical aspects of stock assessment. It is therefore important that the Panel strive for a risk neutral perspective in its reports and deliberations. Assessment results based on model scenarios that have a flawed technical basis, or are questionable on other grounds, should be identified by the Panel and excluded from the set upon which management advice is to be developed. The STAR Panel should comment on the degree to which the accepted model scenarios describe and quantify the major sources of uncertainty Confidence intervals of indices and model outputs, as well as other measures of uncertainty that could affect management decisions, should be provided in completed stock assessments and the reports prepared by STAR Panels.

Recommendations and requests to the STAT Team for additional or revised analyses must be clear, explicit, and in writing. A written summary of discussion on significant technical points and lists of all STAR Panel recommendations and requests to the STAT Team are required in the STAR Panel's report. This should be completed (at least in draft form) prior to the end of the meeting. It is the chair and Panel's responsibility to carry out any follow-up review of work that is required.

Appendix 2: DRAFT AGENDA: CPS STAR PANEL

Tuesday, 21 February		
08h30	Call to Order and Administrative Matters	
	Introductions	Punt
	Facilites, e-mail, network, etc.	Sweetnam
	Work plan and Terms of Reference	Griffin
	Report Outline and Appointment of Rapporteurs	Punt
09h00	Pacific Sardine survey-based assessment presentation	Hill/Crone
10h00	Break	
10h30	Pacific Sardine model-based assessment presentation	Hill/Crone
11h30	Acoustic and trawl survey	Zwolinski
12h00	Bayesian estimates of spawning fraction	Dorval
12h30	Lunch	
13h30	Pacific Sardine assessment presentation (continue)	Hill/Crone
14h30	Panel discussion and analysis requests	Panel
15h00	Break	
15h30	Public comments and general issues	
17h00	Adjourn	

Wednesday, 22 February		
08h00.	Assessment Team Responses	Hill/Crone
10h30	Break	
11h00.	Discussion and STAR Panel requests	Panel
12h30	Lunch	
13h30	Report drafting	Panel
15h00	Break	
15h30	Assessment Team Responses	Hill/Crone
16h30	Discussion and STAR Panel requests	
17h00	Adjourn	

Thursday, 23 February		
08h00.	Assessment Team Responses	Hill/Crone
10h30	Break	
11h00.	Discussion and STAR Panel requests	Panel
12h30	Lunch	
13h30	Report drafting	Panel
15h00	Break	
15h30	Assessment Team Responses	Hill/Crone
16h30	Discussion and STAR Panel requests	
17h00	Adjourn	

Friday, 24 February		
08h00.	Assessment Team Responses	Hill/Crone
10h30	Break	
11h00.	Discussion and STAR Panel requests	Panel
12h30	Lunch	
13h30	Finalize STAR Panel Report	Panel
15h00	Break	
15h30	Finalize STAR Panel Report	Panel
17h00	Adjourn	

Appendix 3: STAR Panel Summary Report (Template)

- Names and affiliations of STAR Panel members

- List of analyses requested by the STAR Panel, the rationale for each request, and a brief summary the STAT responses to each request

- Comments on the technical merits and/or deficiencies in the assessment and recommendations for remedies

- Explanation of areas of disagreement regarding STAR Panel recommendations
    - Among STAR Panel members (including concerns raised by the CPSMT and CPSAS representatives)
    - Between the STAR Panel and STAT Team

- Unresolved problems and major uncertainties, e.g., any special issues that complicate scientific assessment, questions about the best model scenario, etc.

- Management, data or fishery issues raised by the public and CPSMT and CPSAS representatives during the STAR Panel

- Prioritized recommendations for future research and data collection

Appendix 3: Panel membership or other pertinent information from the panel review meeting

STAR Panel Members:
André Punt (Chair), Scientific and Statistical Committee (SSC), Univ. of Washington
Will Satterthwaite, SSC, Southwest Fisheries Science Center
Evelyn Brown, SSC, Lummi Natural Resources, LIBC
Jon Vølstad, Center for Independent Experts (CIE)
Gary Melvin, Center for Independent Experts (CIE)

Pacific Fishery Management Council (Council) Representatives:
Kerry Griffin, Council Staff
Diane Pleschner-Steele, CPSAS Advisor to STAR Panel
Lorna Wargo, CPSMT Advisor to STAR Panel

Pacific Sardine Stock Assessment Team:
Kevin Hill, NOAA / SWFSC
Paul Crone, NOAA / SWFSC
Juan Zwolinski, NOAA / SWFSC

Other Attendees
Dale Sweetnam, SWFSC
Alan Sarich, CPSMT/Quinault Indian Nation
Emmanis Dorval, SWFSC
Chelsea Protasio, CPSMT/CDFW
Kirk Lynn, CPSMT/CDFW
Ed Weber, SWFSC
Josh Lindsay, NMFS WCR
Erin Kincaid, Oceana
Al Carter, Ocean Gold
Jason Dunn, Everingham Bros Bait
Nick Jurlin, F/V Eileen
Neil Guglielmo, F/V Trionfo
Andrew Richards, Commercial
Hui-Hua Lee, SWFSC
Bev Macewicz, SWFSC
Chenying Gao, Student
Steven Teo, SWFSC
Kevin Piner, SWFSC
Andy Blair, Commercial
Jamie Ashley, F/V Provider
John Budrick, CDFW
Steve Crooke, CPSAS
Gilly Lyons, Pew Trusts

CDFW – California Department of Fish and Wildlife
CPSAS - Coastal Pelagic Species Advisory Subpanel
CIE – Council on Independent Experts
CPSMT - Coastal Pelagic Species Management Team
CWPA – California Wetfish Producers Association

SSC - Scientific and Statistical Committee (of the Pacific Fishery Management Council)
SWFSC - Southwest Fisheries Science Center (National Oceanic and Atmospheric Administration)
WCR – West Coast Region